

## SECTION IV. THEORY OF OPERATION

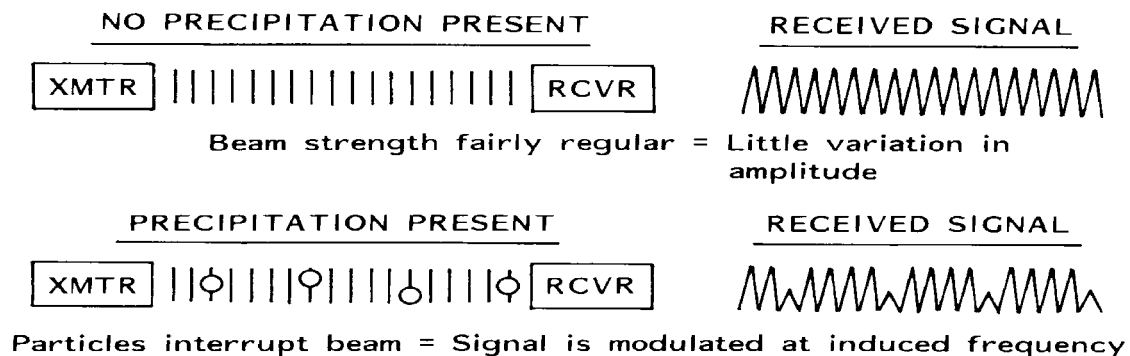
### 7.4.1 INTRODUCTION

This section describes how the ASOS present weather sensor functions to detect and identify precipitation. The operating theory is presented in two levels of detail. The first level introduces the principles of operation and describes sensor operation on a simplified block diagram level. The second level describes the sensor's individual functional areas in a detailed block diagram that allows isolation of faulty field replaceable units (FRU's).

### 7.4.2 SIMPLIFIED BLOCK DIAGRAM DESCRIPTION

The following paragraphs describe the basic operation of the present weather sensor, and the physical principles upon which the sensor is designed. A simplified block diagram of the sensor's operation introduces the basic sensor components and describes their functional relationships.

**7.4.2.1 Principles of Operation.** The ASOS present weather sensor detects the presence of precipitation by using an infrared light beam. A simplified illustration of the sensing technique is provided in Section 7.4.1. The infrared light is pulsed by the transmitter at a high rate (50 kHz) and passed through a volume of air where it is then detected by the receiver. The receiver uses a horizontal slit aperture, which maximizes its sensitivity to vertically falling precipitants. When there is no precipitation, the light pulses pass directly through the air. Thus, the frequency of the light pulses at the receiver is the same as the frequency of the light pulses transmitted. Also, with no precipitation, the power level received by the receiver is at a maximum. If there is any precipitation such as rain or snow in the volume of air, some of the light pulses are blocked by the precipitation particles. The result is a modulation of the light signal, which changes the frequency composition of the signal detected at the receiver. The physical properties of the precipitation such as the particle size, number, and falling velocity directly affect the frequency composition of the received signal. In actuality, the physical properties of the light pulses and the precipitation particles cause more of a partial shadowing than actual blocking of the light pulses. The effects, however, are still the same. Thus, by measuring the frequency components and power levels at the receiver, the presence and type of precipitation can be determined.



**Figure 7.4.1. Precipitation Effects on Received Signal**

**7.4.2.2 Simplified Block Diagram Description.** A simplified block diagram of the present weather sensor is provided in Section 7.4.2. The transmitter modulator in the main electrical enclosure assembly generates a 50 kHz transmit signal, which is output to the transmitter head. The infrared transmitter generates light pulses that are formed into a semicoherent beam by optics in the transmitter head. The transmitted light signal passes through a sample volume of air where it is detected by the receiver head. Optics in the receiver head focus incoming light onto an infrared detector where it is converted back into an electrical signal. The received signal is then amplified and output to an automatic gain control (AGC). The AGC compensates the

received signal to overcome effects of temperature changes, component aging, dusty optics, and haze or fog. AGC output is demodulated and sent to the signal processors. Signal processors filter the demodulated signal to determine its frequency component content. There are actually four channels of signal processing: the low band (25 to 250 Hz) channel, the high band (1 to 4 kHz) channel, the particle count channel, and the carrier channel. The use of these channels is summarized as follows:

- a. The particle count channel and the high and low band channels are used for precipitation state (yes/no) identification.
- b. The ratio of high band to low band signal strength is used for precipitation type (snow/rain) identification.
- c. The strength of the high band signal is used to determine intensity of rain (R-, R, or R+).
- d. The strength of the low band signal is used to determine intensity of snow (S-, S, or S+).
- e. The carrier channel is tuned to the carrier signal to monitor the received signal strength and detect accidental beam blocking or light source failure.

The outputs of the signal processing channels are applied to the microprocessor control logic where they are converted to digital form and processed. The microprocessor samples channel data once every 5 seconds and continually runs a present weather algorithm (once per minute). As part of the algorithm, the microprocessor maintains an adaptive baseline of 1-minute averages of the three data channels (low band, high band, and particle count). Because of this adaptive baselining technique, the sensor requires several minutes to stabilize (establish its baseline) after power up or calibration adjustments. When polled by the DCP, the microprocessor outputs its present weather data in RS-232 format to the fiberoptic module. The fiberoptic module relays all of the data messages between the present weather sensor and the DCP using a fiberoptic data link.

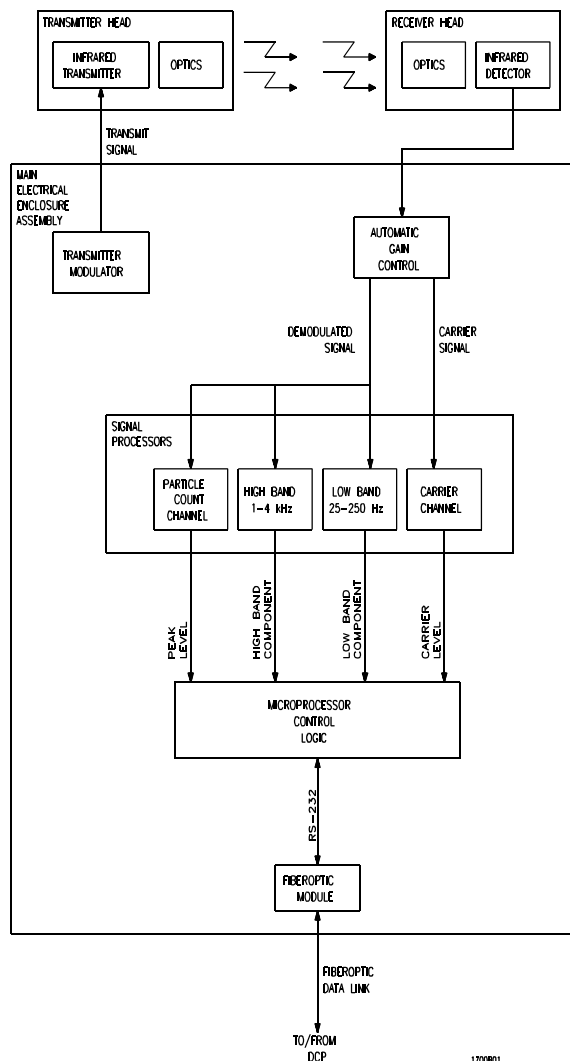
### 7.4.3 DETAILED BLOCK DIAGRAM DESCRIPTION

**7.4.3.1 General.** The present weather sensor (Figure 7.4.3) detects current precipitation conditions via an infrared light beam. The infrared beam is transmitted through a sample volume of air, detected by an infrared receiver, and then analyzed for frequency components that indicate precipitation. The results of these processes are then transferred in digital format to the DCP.

**7.4.3.2 Transmitter Board (2MT2A1A1A1).** The transmitter board in the card rack assembly of the main electrical enclosure assembly generates the carrier frequency signal for the transmitter head. A voltage controlled oscillator (VCO) generates a 50 kHz signal that is amplified and output to trigger the transmitter's infrared light emitting diode (LED).

**7.4.3.3 Transmitter Head (Part of Frame Assembly 2MT2A2).** The transmitter head houses the emitter board and transmitter optics. The carrier frequency modulation signal input from the transmitter board in the main electrical enclosure assembly card rack assembly is applied to an infrared LED. The LED emits infrared light pulses at the carrier frequency rate (50 kHz). The light pulses are then shaped into a semicoherent light beam by the transmitter optics and passed through a sample volume of air.

**7.4.3.4 Receiver Head (Part of Frame Assembly 2MT2A2).** The receiver head houses the receiver optics, infrared detector, and signal preamplifier. The receiver optics focus the incoming infrared light signal onto a photodiode. This photodiode produces a low level electrical signal that contains all of the characteristics of the precipitation effects on the light beam. The low level electrical signal is then amplified and output to the receiver AGC board in the main electrical enclosure assembly card rack assembly.



**Figure 7.4.2. Present Weather Sensor Simplified Block Diagram**

**7.4.3.5 Receiver AGC Board (2MT2A1A1A8).** The receiver AGC board is located in the card rack assembly in the main electrical enclosure assembly. The receiver AGC board adjusts the signal level input from the receiver head and demodulates the received signal. The receiver AGC board uses a variable feedback amplifier to automatically adjust the signal level to an optimum level for output to the signal processor boards. This AGC amplifier circuit senses the amplitude of the incoming signal and adjusts the feedback (gain) of the amplifier to generate a normalized signal for further processing. The signal is then demodulated to separate the carrier signal component from the modulation signal component. These two signals are then output to the signal processor boards for further processing.

**7.4.3.6 Signal Processor Board No. 1 (2MT2A1A1A7).** Signal processor board No. 1 contains the signal processing channels for the carrier signal and the low band (25 to 250 Hz) frequency components. The carrier channel is filter tuned to the carrier frequency and converts the carrier frequency component to a dc voltage signal for output to the microprocessor board. The carrier channel is used by the sensor to verify the presence of the carrier signal. If there is no signal output from this channel, then the sensor reports a failure due to optical path blockage or a transmitter/receiver failure. The low band frequency channel is tuned to the frequency band from 25 to 250 Hz. This channel converts any signal components in the low band range into a dc voltage signal that is output to the microprocessor board. The sensor uses this channel, in conjunction

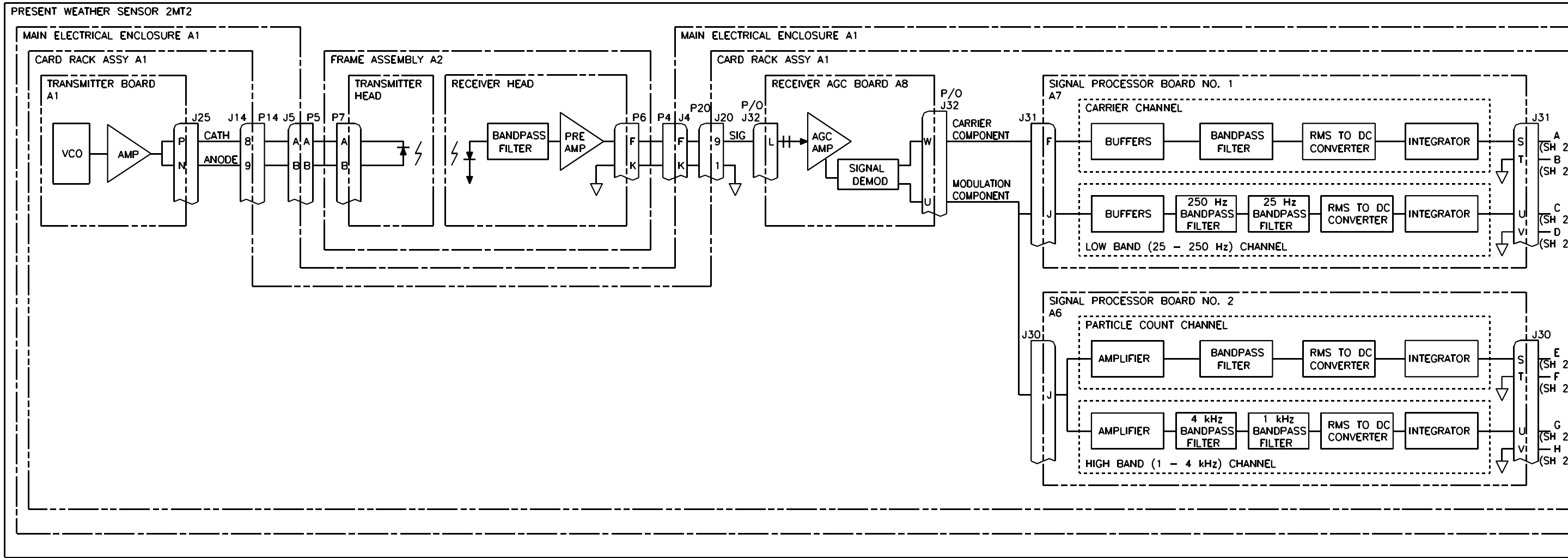
with the particle count and high band channels, to determine the state (yes/no) of precipitation. The ratio of this channel with respect to the high band channel is used to determine the type (rain/snow) of precipitation. Finally, the strength of the low band output signal is used to determine intensity of snow (S-, S, or S+).

**7.4.3.7 Signal Processor Board No. 2 (2MT2A1A1A6).** Signal processor board No. 2 contains the signal processing channels for the particle count signal and the high band (1 to 4 kHz) frequency components. The output of the particle count channel is used to detect the start (yes/no) of a precipitation event. The high band frequency channel is tuned to the frequency band from 1 to 4 kHz. This channel converts any signal components in the high band range into a dc voltage signal that is output to the microprocessor board. The sensor uses this channel, in conjunction with the particle count and low band channels, to determine the state (yes/no) of precipitation. The ratio of this channel to the low band channel is used to determine the type (rain/snow) of precipitation. Finally, the strength of the high band output signal is used to determine intensity of rain (R-, R, or R+).

**7.4.3.8 Microprocessor Board (2MT2A1A1A3).** The microprocessor board contains all of the control logic within the present weather sensor. The microprocessor control logic operates under sensor software control to sample the outputs of each of the signal processor channels and determine the presence and type of precipitation. The sampling of the signal processor channels is performed one channel at a time. The signal outputs of each of the channels are selected through an analog multiplexer for application to an analog-to-digital (A/D) converter. The A/D converter converts the analog voltage signal input into a digital output, which is then read and processed by the microprocessor control logic. This same circuit is used to monitor the power supply voltages used by the sensor electronics assemblies.

**7.4.3.9 Fiberoptic Module (2MT2A1A2A1).** The fiberoptic module provides a two-way serial data communication link between the present weather sensor and the DCP. The module converts the optical data from the DCP to RS-232 serial data for the sensor's microprocessor control logic. The module also converts RS-232 data from the sensor's microprocessor control logic to optical data to be sent to the DCP. The fiberoptic link with the DCP consists of separate transmit and receive fiberoptic cables.

**7.4.3.10 Power Distribution.** The present weather sensor has two ac power inputs from the DCP (Figure 7.4.4). One ac power input is the power source for the sensor's bar heater assembly. The second ac power input is the power source for the sensor's digital and analog electronics. The heater power input from the DCP is controlled by two thermostats. The first (failsafe) thermostat closes at 80 degrees F to enable the heater circuit. The second thermostat then turns on the heater when enclosure temperature drops to 40 degrees and turns the heater off when the enclosure temperature rises to 60 degrees. The failsafe thermostat then opens to disable the heater circuit when the temperature of the enclosure rises to 110 degrees. Heater power supply PS1 generates +24 vdc heater power, which is routed to the card rack assembly. From the card rack assembly, the +24 vdc power is routed as +24V CONTINUOUS power to the lens heaters of both the transmitter and the receiver. The heater power supply also contains a relay that is controlled by Microprocessor Board A1A3. This relay switches +24 vdc power and routes it back to the card rack assembly, where it is applied as +24V HTR SW to the hood heaters on both the transmitter and receiver heads. This allows the microprocessor to control the hood heaters on the transmitter and receiver heads. Analog power supply PS2 provides +12 vdc and -12 vdc for Signal Processor Board No. 1 A1A7, Signal Processor Board No. 2 A1A6, Receiver AGC Board A1A8, and the receiver head. Digital power supply PS3 provides +12 vdc, -12 vdc, and +5 vdc power for Transmitter Board A1A1 and Microprocessor Board A1A3.



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Figure 7.4.3. Present Weather Sensor Detailed Block Diagram (Sheet 1 of 2)

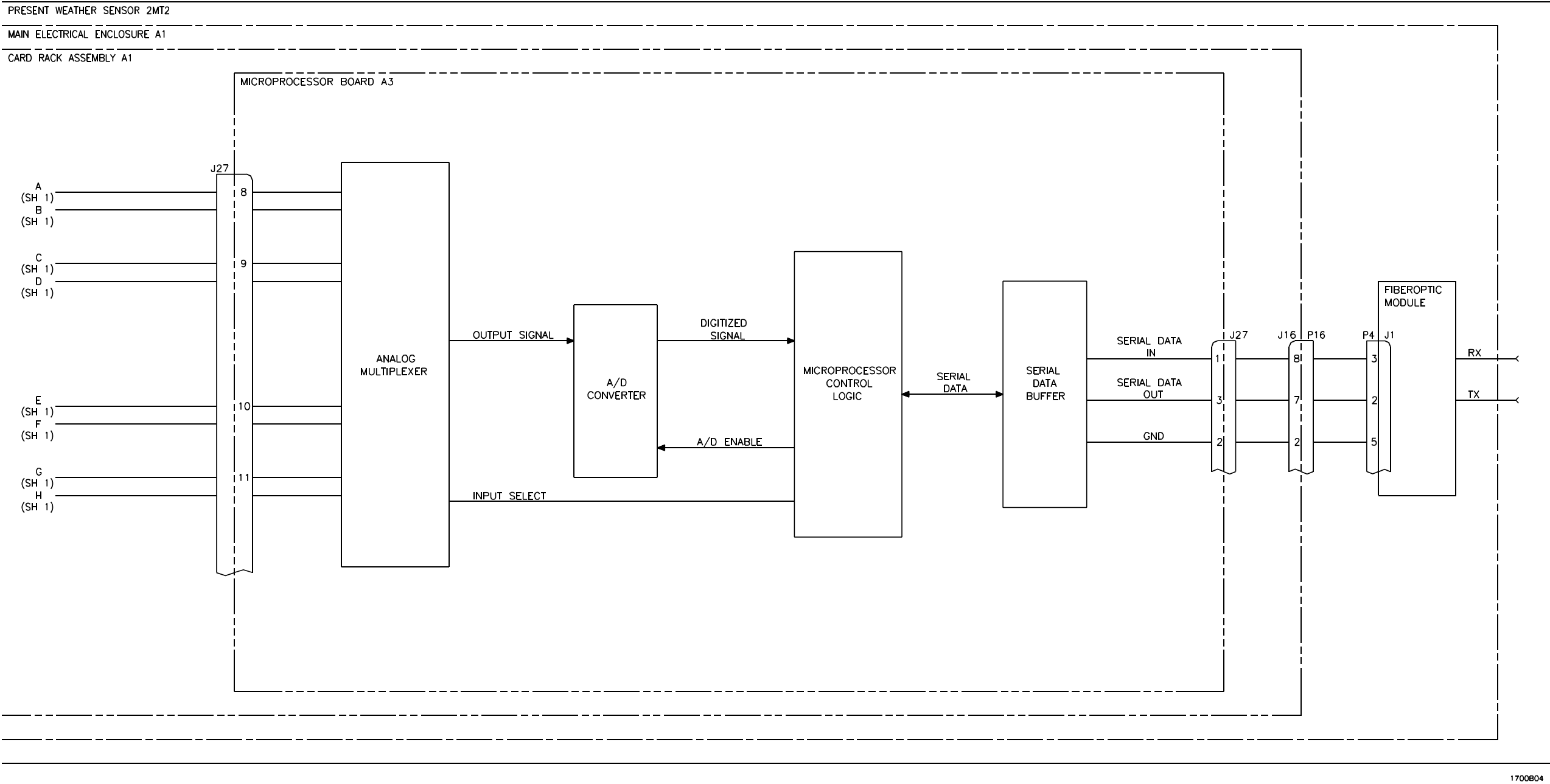


Figure 7.4.3. Present Weather Sensor Detailed Block Diagram (Sheet 2)

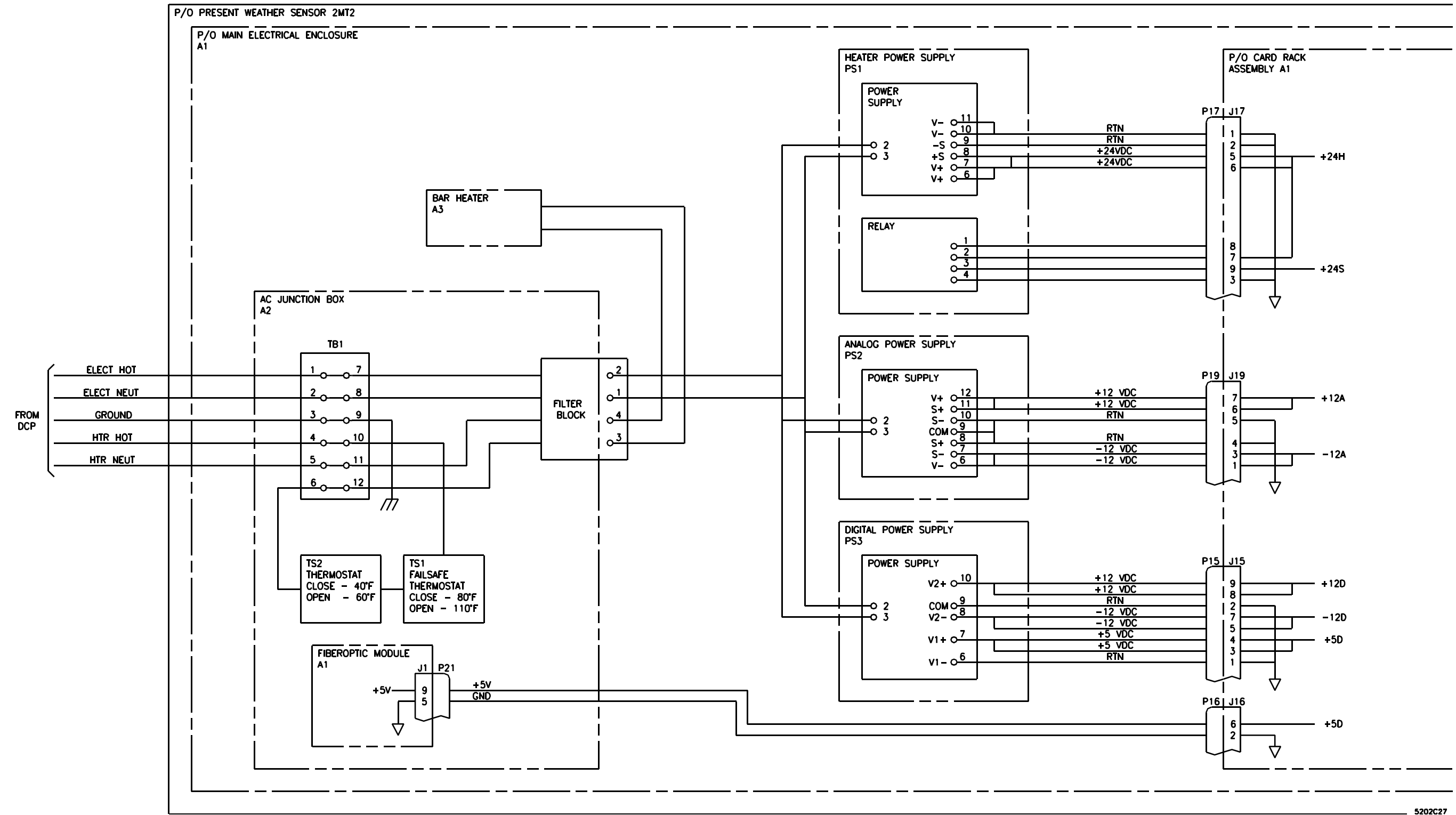


Figure 7.4.4. Present Weather Sensor AC/DC Power Distribution (Sheet 1 of 2)

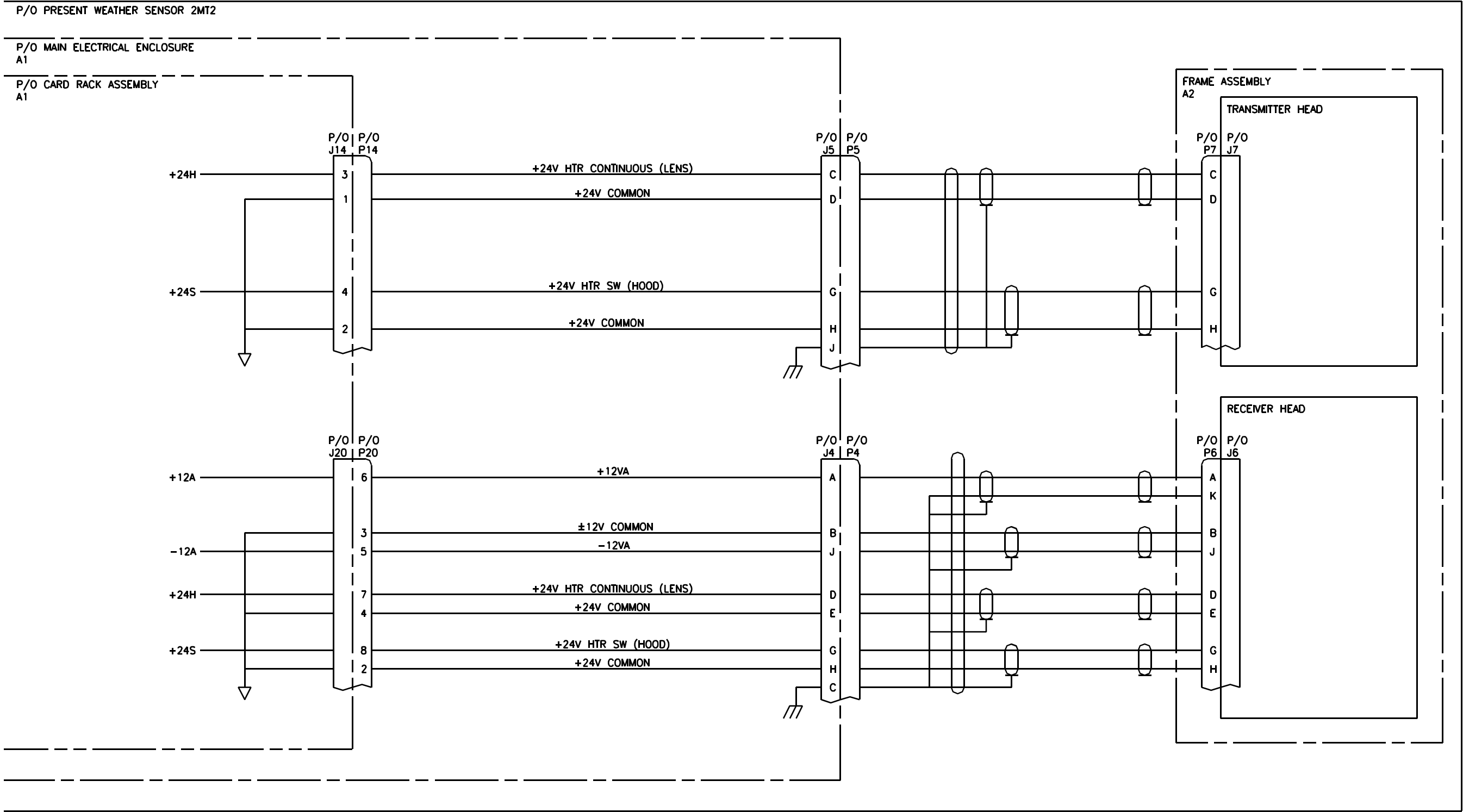


Figure 7.4.4. Present Weather Sensor AC/DC Power Distribution (Sheet 2)

#### 7.4.4 POLL/FRAME FORMATS

The present weather sensor responds to three different types of single character ASCII polls issued by the DCP or the technician during calibration. The poll character transmitted to the present weather sensor should be a single character only (transmitted at 1200 baud, 1 start bit, 8 data bits, no parity, and 1 stop bit), not followed by any other characters or control codes. The poll codes and description are listed below:

<u>DCP Request</u>	<u>Description</u>
A	Send routine data
B	Send simulation data
C	Send data and raw data

The type A poll (short message format) is used for normal operation. This poll is issued once every 60 seconds by the DCP, and in response, the present weather sensor transmits a 17-character string that contains present weather, precipitation amount, sensor status, and frame checksum information. The type B poll (simulation data) is used for field test and diagnostic purposes during calibration. This mode outputs a fixed (never changing) string of 17 characters in the same format as above, but with fixed dummy data. The type C poll is a long (45 characters) output format which includes present weather, precipitation intensity, and full raw data along with status and checksum data. This poll is used for performing normal polls along with acquiring raw sensor data for evaluation or diagnostic purposes. Each of the three poll types are discussed in more detail in the sections below. The various fields, portions of which are common to all formats, are described in paragraph 7.4.4.4. Paragraph 7.4.4.5 details the status code field of the type C poll.

**7.4.4.1 Type A - Routine Data Poll.** This paragraph explains the format of the present weather sensor data frame that is transmitted in response to the type A poll. The present weather sensor ASCII routine data string is 17 bytes long and is formatted as follows:

Format	[STX]	W	w	w	P	p	p	p	p	S	s	s	s	s	c	c	[CR]
Byte	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

<u>Byte</u>	<u>Description</u>	<u>Value</u>
1	Start of transmission	[STX]
2	Weather type marker	W
3-4	Present weather field	ww
5	Precipitation amount marker	P
6-9	Precipitation amount field	pppp
10	Status field marker	S
11-14	Status field	ssss
15-16	Checksum field	cc
17	Carriage return	[CR]

**7.4.4.2 Type B - Simulated Data Poll.** This paragraph explains the format of the present weather sensor data frame that is transmitted in response to the type B poll. The present weather sensor ASCII diagnostic data string is 17 bytes long and is formatted as follows:

Format	[STX]	W	N	P	P	1	2	3	4	S	5	6	7	8	9	0	[CR]
Byte	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Byte	Description	Value
1	Start of transmission	[STX]
2	Weather type marker	W
3-4	Present weather (dummy data)	NP
5	Precipitation amount marker	P
6-9	Precipitation amount (dummy data)	1234
10	Status field marker	S
11-14	Status field (dummy data)	5678
15-16	Checksum field (dummy data)	90
17	Carriage return	[CR]

7.4.4.3 **Type C - Full Raw Data Poll.** This paragraph explains the format of the present weather sensor data frame that is transmitted in response to the type C poll. The present weather sensor ASCII full raw data string is 45 bytes long and is formatted as follows:

Format	[STX]	W	w	w	P	p	p	p	p	S	s	s	s	s	c	c	X
Byte	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

Format	n	n	n	z	z	z	L	n	n	n	b	b	b	K	n	n	n
Byte	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34

Format	b	b	b	H	n	n	n	b	b	b	[CR]
Byte	35	36	37	38	39	40	41	42	43	44	45

Byte	Description	Value
1	Start of transmission	[STX]
2	Weather type marker	W
3-4	Present weather field	ww
5	Precipitation amount marker	P
6-9	Precipitation amount field	pppp
10	Status field marker	S
11-14	Status field	ssss
15-16	Checksum field	cc
17	Carrier raw data field marker	X
18-20	Carrier 1 min average raw data	nnn
21-23	Low/particle/high lock indicator	zzz
24	Low raw data field marker	L
25-27	Low 1 min average raw data	nnn
28-30	Low baseline	bbb
31	Particle raw data field marker	K
32-34	Particle 1 min average raw data	nnn
35-37	Particle baseline	bbb
38	High raw data field marker	H
39-41	High 1 min average raw data	nnn
42-44	High baseline	bbb
45	Carriage return	[CR]

7.4.4.4 **Field Description.** This paragraph describes the format of the various fixed fields as they are used in the three formats above.

- a. The capital letters W, P, S, X, L, K, and H above serve as place markers for the weather, precipitation, status, carrier, low, particle, and high data fields to follow. These markers are fixed in position and coding. They are included within the format to simplify manual interpretation of the sensor output.
- b. w w is a 2-byte field indicating present weather. The weather code contained in this field will be one of the following:

L-	Light drizzle	S-	Light snow
L_	Moderate drizzle	S_	Moderate snow
R-	Light rain	S+	Heavy snow
R_	Moderate rain	P?	Unknown precipitation
R+	Heavy rain	ER	Error condition
__	No precipitation	P_	Mixed precipitation
--	Startup code		

The \_ (underline) character represents an ASCII space character and is shown only for readability. The -- code will be output in this and other data fields during approximately the first 60 seconds after reset or power up of the sensor.

- c. p p p p is a 4-byte field indicating the precipitation amount of equivalent water content for snow. Zero is formatted as four zeros (0000). The number is a floating point format, varying from 0.01 to 9999. Units are millimeters-per-hour rain rate, averaged over a 1-minute period.
- d. s s s s is a four-character field containing ASCII encoded hex value reserved for error and status codes. Each character represents a 4-bit field of binary information. The 4-bit field contains status information of the FRU's. Paragraph 7.4.4.5 contains detailed breakdown.
- e. c c is a 2-byte field containing ASCII encoded 8 bit hex value for a modulo 256 checksum of the data between but not including [STX] and c c.
- f. n n n is a 3-byte ASCII numeric field indicating the corresponding 1-minute averaged raw data in tens of millivolts. Leading/unused positions are filled with zeros. Valid values are -99 to 999. Overflows and underflows are represented as 999 and -99, respectively.
- g. z z z is a three-character ASCII numeric field indicating the lock on (0) or off (1) status of the low, particle counting, and high channels, respectively.
- h. b b b is a 3-byte ASCII numeric field indicating the respective data channel adaptive baseline value in tens of millivolts for the current algorithm (1 minute) processing cycle. Leading/unused positions are filled with zeros. Valid values are -99 to 999.

7.4.4.5 **Status Field Encoding.** The status field, denoted by s s s s (4 bytes) in the present weather sensor data output format, is a 4-byte field of sensor status bytes. Each status byte is represented in the data field as an ASCII-encoded hex-formatted nibble (0-F). Each of the 4 bits, represented by each of the 4 nibbles, represents the status of a particular field replaceable unit (FRU) or of a particular system condition. Each status byte character must be converted to binary in order to identify which bits are set or cleared. Table 7.4.1 shows what the corresponding binary nibble is for each of the 16 possible hex characters that may be seen in the status string.

Table 7.4.1. Hex - Binary Nibble Conversion Chart

ASCII -Encoded Hex Character	Binary Nibble			
	(msb)			(lsb)
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
A	1	0	1	0
B	1	0	1	1
C	1	1	0	0
D	1	1	0	1
E	1	1	1	0
F	1	1	1	1

Each bit is set (bit = 1) to indicate that a problem exists in that FRU or that a specified event or condition is true. A bit will be cleared (bit = 0) if that FRU is good or that condition is false. The actual meaning of each bit is given on Section 7.4.5. The bits shown as 0 are low and are reserved for future use. The RESET bit will normally be low (0), except after power-up or system reset (hardware or software reset). Upon such an event and for 5 minutes afterward, the RESET bit will be high (1). ASOS disregards data taken during these 5 minutes. (This time is required for the present weather sensor averaging routine to stabilize.) In normal operation (excluding the first 5 minutes after reset or power-up), the status bytes will be all low (0000). A non-zero character in any of the four positions indicates the suspected failure of an FRU which causes ASOS to take action to alert maintenance personnel of a problem. In addition, data from the present weather sensor will be disregarded and a missing report issued. (Note that the present weather sensor does not necessarily stop outputting data when a status bit flags an error condition.) A summary of the active status bits and the corresponding FRU's and assembly numbers are provided in table 7.4.2.

**NOTE**

Byte 0 is transmitted first.

<b>Output String Position</b>					<b>Relative Position</b>
Character 11	FRU8	FRU7	FRU2	FRU3	Byte 1
Character 12	FRU4	FRU5	FRU9	FRU1	Byte 2
Character 13	RESET	0	0	0	Byte 3
Character 14	0	0	0	0	Byte 4
	Bit 3	Bit 2	Bit 1	Bit 0	

Figure 7.4.5. OWI-240 Status Bit Identification

**Table 7.4.2. Status Bit/FRU Summary**

<b>FRU Number</b>	<b>Item</b>	<b>Reference Designator</b>
FRU1	Frame assembly	2MT2A2
FRU2	Transmitter board	2MT2A1A1A1
FRU3	Receiver AGC board	2MT2A1A1A8
FRU4	Signal processor board #1	2MT2A1A1A7
FRU5	Signal processor board #2	2MT2A1A1A6
FRU6	Microprocessor board	2MT2A1A1A3
FRU7	Analog power supply	2MT2A1PS2
FRU8	Digital power supply	2MT2A1PS3
FRU9	Heater power supply	2MT2A1PS1